

The Status of the Deep Space Network for the Cassini Radio Science Experiments

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Abstract

The Deep Space Network (DSN) is operated by the Jet Propulsion Laboratory (JPL) of the California Institute of Technology for the National Aeronautics and Space Administration (NASA). The Frequency and Timing System (FTS) of the DSN as it existed before the Cassini program easily met the requirements for all the NASA deep space missions. The requirements and the performance of the present DSN FTS are given. The requirements of the Cassini Radio Science experiments are greater than that of the present performance of the DSN FTS. These requirements are given and the serious changes that are being implemented in the DSN to meet these requirements are given, as well as the expected changes in the DSN FTS performance to meet these requirements. These changes include new frequency standards (Linear Ion Trap with Cryogenic local Oscillator), improved long term stability (Stabilized Fiber Optic Distribution for the remote antennas), and improved short term stability (I-Band Fiber Optic Distribution with Clean-up Loops for the remote sites.)

INTRODUCTION

The Deep Space Network (DSN) is a global navigation, tracking, and data collection network with stations in Tidbinbilla, Australia; Robledo, Spain; and Goldstone, California. It is operated for the National Aeronautics and Space Administration (NASA) by the Jet Propulsion Laboratory (JPL), California Institute of Technology.

Sonic improvements to the Frequency and Timing System (FTS) of the Deep Space Network (DSN) are necessary to meet the requirements of the Cassini project for the Radio Science portion of the mission. The Cassini requirements on the FTS are shown in Figure 1.

The stations in Spain and Australia are all collocated, while some of the ones at Goldstone are remotely located (as far as 27 km from the central group of collocated antennas). The collocated stations have had some recent improvements (fiber optic distribution to the various collocated antennas to reduce the diurnal and air-conditioning induced phase variations, 100 Mbit/s distribution to improve phase noise) and meet the Cassini requirements.

Figure 2 shows the Goldstone complex. One of the stations which will be used for the Cassini Radio Science Experiments is the Deep Space Station 25 (DSS 25). It is located 17 km from the FTS center. The frequency distribution to this station is shown on the figure. This distribution uses single-mode fiber optic cable that is 1.5 m underground in order to reduce the temperature variations and resulting delay, or phase, variations. However, there are six access vaults where the cables are spliced or diverted to other locations. These vaults are concrete with steel covers and act as ovens. Where the cables are brought out of the ground to enter the buildings are also locations of large temperature variations. The portion of the cables inside the buildings is subjected to temperature variations due to the cycling of the air-conditioning systems. All these causes result in diurnal and short-term (5 minute to 20 minute) temperature changes and resulting phase changes.

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These are not large enough to affect normal tracking, navigation, or data acquisition, but the Cassini requirements are more stringent, especially for the Ku-band reception at the remote site DSS 25. The phase noise performance of the existing fiber optic link to DSS 25 does degrade the frequency standard performance somewhat, so that has to be improved also,

STABILIZATION OF THE LINK AGAINST THERMAL VARIATIONS

A system has been developed which senses the delay variations in the link and controls the temperature of a section of fiber which is installed in series with the link in order to keep the total delay constant.

IMPROVEMENT OF THE PHASE NOISE

The phase noise contributed by the fiber optic link degrades the performance of the frequency standards that, in this case, consist of a cryogenic oscillator (for short term stability) and a trapped ion frequency standard (for long term stability). The fiber optic link has an inherent phase noise of -130 dBc/Hz , independent of frequency over at least several GHz. The normal operation of the fiber optic distribution uses 100 MHz. In order to improve the performance by 2.0 dB, this special distribution system uses 1 GHz for frequency distribution. The block diagram of Figure 3 shows the combination of the two above improvements.

SYSTEM DESCRIPTION

In Figure 3, the 100 MHz reference signal generated in the Signal Processing Center (DSS 10) is multiplied by 10 to 1 GHz. This modulates the 1310 nm laser. The laser signal is sent through the 4 km delay line and then through the buried fiber optic cable to DSS 25. At DSS 25, the optical signal is detected and a phase locked loop is locked to it. This phase locked loop is based on a 100 MHz VCXO and a times 10 multiplier. The 100 MHz is used for frequency distribution in DSS 25. It is also used to modulate the 1 GHz signal, generating the two side-bands on either side of the 1 GHz carrier. The 1 GHz carrier is suppressed with a notch filter. This signal then modulates a 1310 nm optical carrier which is sent back to DSS 10 over the same fiber. At DSS 10 the signal also passes through the optical delay line and is detected. It is then down-converted to base-band and phase detected with 100 MHz to produce a signal that is proportional to the sine of the phase delay. It then is filtered to produce the correct dynamic performance and is used to drive the temperature control electronics that controls the temperature of the optical delay line by means of Peltier coolers to hold the phase delay constant.

An experimental breadboard of this system has been built and tested in the laboratory. The system reduces the Allan Deviation due to temperature variations by ~ 30 times, enough to satisfy the Cassini requirements. The phase noise contribution is reduced by the theoretical amount, 30 dB, to make the contribution due to the fiber optic link negligible compared to the frequency standards and able to meet the Cassini requirements.

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